Welcome to Midland and the CO$_2$ Conference Week

The Weather is Great (Except for the “Fog”)
Schedule

• Today: EOR Carbon Mgmt Workshop
• Tonight: Reception here at the Midland Center (MC) sponsored by Chevron, Denbury, and GCCSI
• Tomorrow: 8:00 Departure for Field Trip to the Wasson Area, Denver City CO₂ PL Hub and Trinity Wellman Facilities (Don’t be Late)
• Tomorrow: Produced Water Management Shortcourse and Afternoon Field Trip
• Tomorrow Evening: Reception here at the Midland Center (MC) sponsored by Maersk Oil and Chevron
Schedule (Cont’d)

• Thursday: CO₂ Flooding Conference Theme Sessions (Case Histories I & II)

• Reception at the Permian Basin Petroleum Museum sponsored by Kinder Morgan CO₂ and PB SPE (Transport available from MC to Museum and Return)

• Friday: CO₂ Flooding Conference Theme Session ending at Noon with Sandwich Lunch here in the Midland Center
New Strategies While Waiting on CO$_2$?

Steve Melzer

Midland, Texas

Presented at the
2014 EOR Carbon Management Workshop
Midland, Tx
December 9, 2014
New Strategies While Waiting on CO₂

Outline of Talk

- Focus: EOR as the Large Volume User of CO₂
  - A Quick Historical Look at the Phases of CO₂ EOR
- What is Holding Back Further Growth of CO₂ EOR and CCS?
- A Geeky Look Beyond the Current Business Issues: Let’s Examine Emerging Ideas, Trends and What That May Say about Future Markets – Four Key Areas
  1 - CO₂ EOR Moves Below the Oil/Water Contact (ROZ Developments)
  2 - The Unconventional Revolution
  3 - Hydro fracturing the Upper ROZ
  4 - Working More Closely with the Unconventional Reservoir Sub-Industry
    - Produced Water Management
    - NGL By-product Market Making
Focus: EOR as the Large Volume User of CO$_2$

A Quick Historical Look at the History of CO$_2$ EOR
The Phases of CO₂ Enhanced Oil Recovery

PERMIAN BASIN CO₂ EOR PROJECT STARTS

Melzer Consulting
PB Undersupplied Since 2004
Okay, So We’re Undersupplied. We all Know it Takes Time for New Supplies to Come to the Market.....

But What Can be Done While EOR Awaits New CO₂?

Let’s Talk Some Technical Stuff and ‘Market Making’
Enough on the Matters Relating to the Current Business

Let’s Talk Some Technical Stuff and ‘Market Making’
What’s New?

**Area #1**: Expansion of CO$_2$ Flooding Below the Oil/Water Contact (into Residual Oil Zones)
We’ve ID’d Three Types of Residual Oil Zones
(see http://www.melzerconsulting.com/index.php/ongoing-research)
## RESIDUAL OIL ZONE TYPES AND ATTRIBUTES

<table>
<thead>
<tr>
<th>ROZ TYPE</th>
<th>Oil-Water Contact</th>
<th>Base of Oil Saturation</th>
<th>Other Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional Tilt (1)</td>
<td>Horizontal</td>
<td>Tilted</td>
<td>Wedge with thick side Downdip</td>
</tr>
<tr>
<td>Breached Seal and Reaccumulation (2)</td>
<td>Horizontal</td>
<td>Horizontal</td>
<td>Stratified Tar Mats, Anomolously Low GOR</td>
</tr>
<tr>
<td>Hydrodynamic Tilt (3)</td>
<td>Tilted</td>
<td>Horizontal</td>
<td>Wedge with thin side in Direction of Flow (to Spill Point)</td>
</tr>
</tbody>
</table>

Types 1 & 2: Vertically Invaded ‘Natural Waterfloods’
Type 3: Laterally Flushed ‘Natural Waterfloods’
Transition Zone (TZ):
- Water and little oil
- Capillary forces

Residual Oil Zone (ROZ):
- Produces only water
- Immobile oil
- Structural changes (uplift) (Koperna et al. 2006; LaCroix et al. 2009)

From an Aramco Talk in Tulsa*
Transition Zone Vs. ROZ

* SPE 169113• A Laboratory Study to Investigate CO₂ Potential to Mobilize Paleo Oil
  • Ahmed Aleidan
THE CLASSIC CO₂ ENHANCED OIL RECOVERY AND WAG SCHEMATIC
WITH A COMMINGLE RESIDUAL OIL ZONE DEPLOYMENT

In this diagram, the CO₂ injection process is illustrated to enhance oil recovery. The injection wells (MPZ & ROZ) are shown isolated within the well or via separate wells. The produced fluids (oil, gas, and water) are separated and stored. The CO₂ and water injection and production well (commingled) are depicted over the oil/water contact areas, with the oil and water zones labeled as MPZ (Middle Production Zone) and ROZ (Residual Oil Zone). The diagram is adapted from a DOE Drawing.
The CO₂ EOR Phase Chart (Permian Basin)
Residual Oil Zone Flooding Project History and Phases of Development

ROZ Project Starts

- Observation Phase
- Deployment Phase

(Bennett Ranch Unit)
Seminole and Wasson
(Denver Unit)
Residual Oil Zone (ROZ) Field Tests

• As of Now, There are 15 individual projects underway in 8 Different Fields
• All Projects are in the Permian Basin (for now at least)
• All Projects are Using CO₂ EOR Technology
• All Projects are Flooding the ROZ of the San Andres Formation
• Two of these Projects is Flooding a Portion of the Field without a Main Payzone (Greenfield {GF}*)
• Deployment of ROZ Floods is Accelerating with International Interest Growing

* Greenfield = ROZ without an Overlying Main Pay Zone (MPZ) – These Occur In ‘Fairways’
MIDDLE SAN ANDRES FORMATION PALEOGEOGRAPHY
with Location of Industry Documented ROZ Zones/Fields*

- Guadalupe Mountains
- Shelf Margin "reef"
- New Mexico
- Texas
- Delaware Basin
- Open Marine
- Midland Basin
- Midland
- Hobbs
- Central Basin Platform
- Marathon Overthrust Belt
- NORTHEAST SHELF
- NORTHERN SHELF
- EASTERN SHELF
- VACUUM FIELD
- GEORGE ALLEN FIELD
- TALL COTTON PROJECT
- VACUUM FIELD
- WASSON FIELD (3)
- HANFORD FIELD
- SEMINOLE FIELD (5)
- MEANS FIELD
- GOLDSMITH FIELD
- MIDLAND BASIN
- San Angelo
Mapping of Residual Oil Zone Fairways in the Permian Basin and Active Major CO₂ EOR Projects

The four county ROZ “fairway” resource assessment addresses the Slaughter and Roswell Fairways on the northern portion of the Permian Basin, where they merge with the Artesia Fairway.

A series of major oil fields - Wasson, Seminole, Robertson, among others - are located within these four counties. The areas underneath the structural closure of these fields have been excluded from the ROZ “fairway” resource assessment.
What’s New?

Area #2: CO$_2$ Flooding the Unconventional Reservoirs
Key Tight Oil and Gas Shale Plays

* Energy Information Agency

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What’s New?

Area #3: Producing MPZs & ROZs While Waiting for Affordable CO$_2$
Area 3: Post Waterflood Recovery of Oil

• CO₂ EOR has Proven Itself in Many Types of Reservoirs Already Waterfloode (Tertiary Stage)

• CO₂ EOR is Now Proving Itself in the Enormous Targets Associated with Naturally Waterflooded Reservoirs (ROZs)

• What Else Can We Do as We Await the Necessary Volumes of Affordable CO₂ for EOR?

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While We Await CO$_2$ Supplies:

*Horizontally Drilling the Upper ROZ*

- Go to a ROZ Fairway Location, Seek and Secure a Water Disposal Option
- Target the Good Gas/Oil Ratio ROZs (e.g., Highly Fluorescing Intervals)
- Expose a Large Section (e.g., Long Lateral)
- Stimulate the Zone
- Pump Very Large Volumes of the Water Until the Oil “Cut” Comes
- Watch Oil Cuts Rise
Horizontally Drill The Upper ROZ
Then Add the Vertical Wells to Do CO$_2$ EOR and CCUS
What’s New?

**Area #4:** Converting the Produced Water to a Range of Valued Water Products (aka Water Utilization)
Okay, Now What Do We Do About the Huge Volumes of Produced Water?

CO₂ EOR PROCESS FLOW

Adapted from SPE MONOGRAPH Practical Aspects of CO₂ Flooding, Figure 5.1
Potentially Four Valued Products

(5th goes to WAG)

1. Frac Water Sales
2. Drilling Fluids
3. 10-# Brine
4. Fresh Water
Presentation Summary

- Emphasize CO$_2$ EOR with the Concepts of CCS (i.e., CCUS): It is the Very Large Volume Marketplace and Has an Exemplary 40-Year History
- CO$_2$ EOR is Set to Grow - EOR Targets Abound
- Future Could be Very Bright if Storage of CO$_2$ were Coupled with Incremental Oil Recovery Opportunities

.....But
Presentation Summary (Cont’d)

But......

• CO₂ EOR is in a “Slow Growth” Mode at the Moment
  – Existing CO₂ Supplies are Contracted and Maxed Out
  – New Anthropogenic Supplies Are Challenged in Being Able to Close the Cost “Gap” and, in addition, Currently Appears to Bring Extra Burdens of Costs Due to EPA Class VI Requirements

• Where is CO₂ Capture Going? Has the EOR Industry Given up on Anthro CO₂? Are Other Pastures (e.g., Unconventionals) Just too Much Greener?
Presentation Summary (Cont’d)

• What Can be Done to Keep the Momentum and While EOR Awaits New Affordable Supplies?
  – Encourage the U.S. DOE to Keep Charging on Deployment of CO₂ Capture Technologies and the CCUS Partnerships
  – Defang the Class II to VI Transition Rule Mess
  – Examine Horizontally Drilling the Upper ROZ Option to Aggregate the Acreage and Provide Profitability in the Short Term
  – Couple the Unconventional Drilling Water Requirements and Growing Aversion to Proliferating Water Disposal Permits with the Emerging Technologies for Water Processing and Water Production During EOR
Closing Perspective

• The Evidence is Everywhere – the CCUS and Oil/Gas Industry’s Creative Juices are Flowing
  – Unconventional Reservoir Exploitation
  – Residual Oil Zone Identification and CO₂ EOR Exploitation
  – Upper ROZ Play with Horizontal Wells
  – New Ideas for CO₂ Capture
  – Better Understandings of CO₂ Retention During EOR
  – Produced Water Reutilization
  – CO₂ Enhanced Product Recovery
    • Converts a Waste Gas (CO₂) to a Commodity Fluid
    • Produces Oil
    • Produces Water Products (10# Brine, Frac, Drilling & WAG Water, Fresh Water)

• So Here we Go: Getting Moving into an Age of Deployment
Thank You